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Recent Results on $L=1$ Charmed Mesons

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RECENT RESULTS ON L=1 CHARMED MESONS

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ABSTRACT

The E687 Collaboration at Fermilab has observed the following decays of L=1 charm meson states previously observed by other experiments¹⁻⁶ : $D^{*0}(2460) \rightarrow D^+\pi^-$, $D^{*0}(2420) \rightarrow D^{*+}\pi^-$, and $D_s^{*+}(2536) \rightarrow D^{*+}K_s^0$. We present a preliminary measurement for the mass and width of the $D^{*0}(2460)$ and $D^{*0}(2420)$.

1. Introduction

Experiment E687 recorded a large sample of charm in 1990-1991 using a multiparticle magnetic spectrometer that is described elsewhere⁷. The charm was produced by ~200 GeV photons impinging on a beryllium target. Approximately 100 K charm events have been reconstructed using these data. These events have been used to study D^{*} mesons, which are the L=1 bound states of a charm quark and a lighter quark. The quark spins can add to 1 to give the three total angular momentum states, $J^P = 2^+, 1^+$ and 0^+ , or to 0 to give the state, $J^P=1^+$. Unless kinematically forbidden, these mesons decay strongly. The allowed 2-body strong decays of the four spin-parity states are listed in Table I. Conservation of angular momentum, parity and isospin prohibits other such decays.

Table I. Allowed 2-body Strong Decays

State	J^P	Decay Mode (D^{*})	Decay mode (D_s^{*})
$3P_2$	2^+	$D^*\pi, D\pi$	D^*K, DK
$3P_1$	1^+	$D^*\pi$	D^*K
$1P_1$	1^+	$D^*\pi$	D^*K
$3P_0$	0^+	$D\pi$	DK

We present some preliminary results from the study of the decay modes $D^{*0} \rightarrow D^+\pi^-$, $D^{*0} \rightarrow D^{*+}\pi^-$, and $D_s^{*+} \rightarrow D^{*+}K_s^0$ and state how they were obtained.

2. Event Selection

The decay chains investigated are listed Table II. Here, as in the rest of this report, the charge conjugate decays were also included in the analysis. The selection of the D and the D^{*} candidates is described elsewhere⁸. The requirement on the minimum separation, L, between the primary and secondary vertices (possible production and decay vertices for the D), scaled by the uncertainty in the separation, σ , is listed in Table II for the various decay chains.

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The selected D^+ or D^{*+} candidate was combined with the pion tracks in the primary vertex, with momentum above a certain minimum threshold (7 GeV for $D^+\pi^-$ and 5 GeV for the $D^{*+}\pi^-$ combination), to give the D^{**} candidate. The cut on the pion momentum was motivated by the observation, from monte carlo simulation and experimental data, that the background in the D^{**} invariant mass plot is mainly due to soft pions combining with the D^+ or D^{*+} , whereas the pion from the D^{**} decay is expected to be relatively hard. The D_s^{**+} candidate was obtained by combining a D^{*+} with the K_s^0 in the event. The difference ΔM in the invariant mass of the D^{**} or D_s^{**+} candidate, and the D or D^{*+} it decays to, is plotted in figures 1 to 3.

Table II. Vertex separation cuts used for the various decay chains.

Decay Chain	Minimum L/σ
$D^{**0} \rightarrow D^+\pi^-$, $D^+ \rightarrow K^-\pi^+\pi^+$	10
$D^{**0} \rightarrow D^{*+}\pi^-$, $D^{*+} \rightarrow D^0\pi^+$, $D^0 \rightarrow K^-\pi^+$	1
$D^{**0} \rightarrow D^{*+}\pi^-$, $D^{*+} \rightarrow D^0\pi^+$, $D^0 \rightarrow K^-\pi^+\pi^-\pi^+$	3
$D_s^{**+} \rightarrow D^{*+}K_s^0$, $D^{*+} \rightarrow D^0\pi^+$, $D^0 \rightarrow K^-\pi^+$	3
$D_s^{**+} \rightarrow D^{*+}K_s^0$, $D^{*+} \rightarrow D^0\pi^+$, $D^0 \rightarrow K^-\pi^+\pi^-\pi^+$	5

3. The D^{**} mass spectra

The $D^+\pi^-$ invariant mass spectrum (figure 1) shows a pronounced peak at $\Delta M \sim 600$ MeV. This is consistent with being due to the $D^{**}(2460)$ decaying to $D^+\pi^-$. There is an additional enhancement at $\Delta M \sim 420$ MeV. This is believed to be due to the $D^{**0}(2420)$ and $D^{**0}(2460)$ decaying to $D^{*+}\pi^-$, with the D^{*+} subsequently decaying to a D^+ and a π^0 . The spectrum was fit with a background function added to three Breit-Wigner peaks, broadened by gaussians of width 7 MeV, to correct for the spectrometer resolution. The masses and widths of the two lower peaks were fixed at values expected,

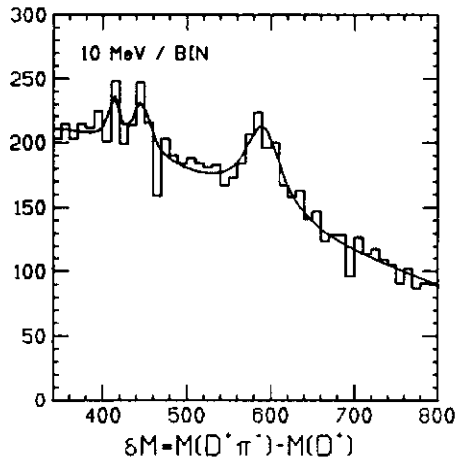


Fig 1. $D^+\pi^-$ mass spectrum

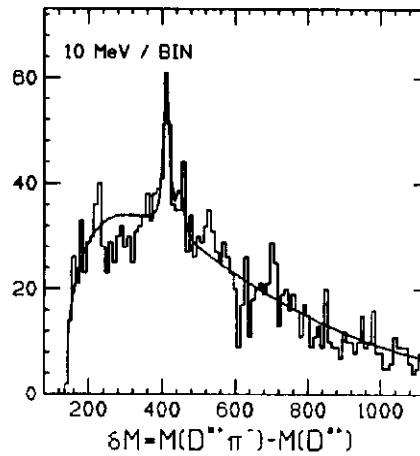


Fig 2. $D^{*+}\pi^-$ mass spectrum

using data from the PDG (Particle Data Group), for $D^{**}(2420)$ and $D^{**}(2460)$. For the remaining peak, we obtain $\Delta M = 593 \pm 4$ MeV, which corresponds to a mass of 2460 ± 4 MeV for the D^{**} state, 42 ± 10 MeV for the natural width, and 501 ± 65 for the number of events.

The 2^+ and the 1^+ states can decay to $D^{**}\pi^-$. The 2^+ state decays through a D-wave resulting in a distribution in $\cos\alpha$ proportional to $\sin^2\alpha$, where α is the angle between the pions from the decay of the D^{**} and the D^{**} , measured in the D^{**} rest frame. The 1^+ states can decay through an S-wave or D-wave resulting in distributions that are flat and proportional to $(1+3\cos^2\alpha)$ respectively. The 2^+ state was practically eliminated by requiring that $\cos\alpha > .8$. The resulting distribution for $D^{**}\pi^-$ is shown in figure 2. It was fit with a background function added to two Breit-Wigner peaks, broadened by gaussians of width 4 MeV, the mass and width of one being fixed at values obtained from PDG for the $D^{**}(2460)$. For the other peak, we obtain $\Delta M = 412 \pm 3$ MeV, which corresponds to a mass of 2422 ± 3 MeV for the D^{**} state, 14 ± 8 MeV for the natural width, and 81 ± 26 for the number of events.

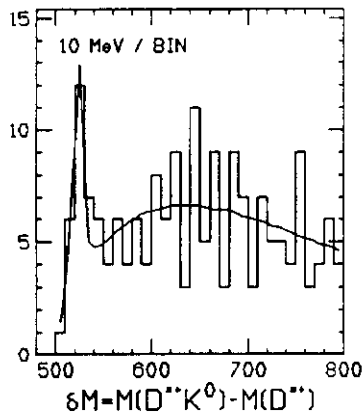


Fig 3. $D^{**} K_s^0$ mass spectrum

The $D^{**} K_s^0$ mass spectrum (figure 3) was fit to a background function added to a Breit-Wigner peak broadened with a gaussian of width 5 MeV. We obtain $\Delta M = 525 \pm 3$ MeV, which corresponds to a mass of 2533 ± 3 MeV for the D_s^{**} state, 12 ± 6 MeV for the natural width, and 25 ± 7 for the number of events. The systematic error in this measurement of the width is believed to be large compared to the statistical error.

The errors quoted in the measurements in this section are statistical only. The systematic errors are under investigation.

4. Conclusions

We have observed the state $D_s^{**}(2536)$. The state was previously observed only in e^+e^- colliding beam experiments^{3,5} and a $\bar{\nu}$ -n collision experiment⁶. We have preliminary measurements for the mass and width of the $D^{**}(2460)$ and the $D^{**}(2420)$. Previous measurement of the mass and width of the latter come from e^+e^- colliding beam experiments^{3,4}.

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